Performance at testbeam and simulation of the CALICE SiW ECAL prototype

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Outline

- The SiW-ECAL
  - Few slides taken from R. Poeschl's talk
- Testbeam setup at DESY2021-2022
- Detector commissioning and single cell performance
  - Pedestal & noise
  - MIP
- Low energetic electron showers
- Next step: high energy showers at CERN (with AHCAL)

Thanks to R. Poeschl, Y. Okugawa, J. Kunath, V. Boudry, T. Suehara, F. Jimenez, H. García for material for this talk

Thanks to the engineering teams of IJCLab, LPNHE and LLR

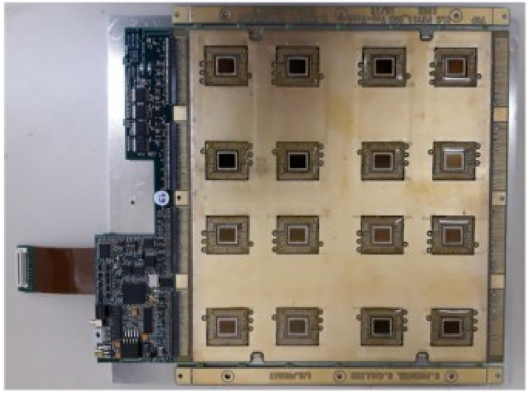
FEV zoo (see R. Poeschl's talk)

- In recent years the SiW ECAL has developed and used several PCB variants
  - To make sure that you don't get lost, here comes an introduction

FEV10-12

- ASICs in BGA Package
- Incremental modifications From v10 -> v12
- Main "Working horses" since 2014

FEV_COB



- ASICs wirebonded in cavities
  - COB = Chip-On-Board
- Current version FEV11_COB
- Thinner than FEV with BGA
- External connectivity compatible with BGA based FEV10-12

FEV13

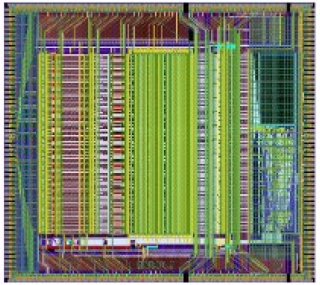
- Also based on BGA packaging
- Different routing than FEV10-12
- Different external connectivity

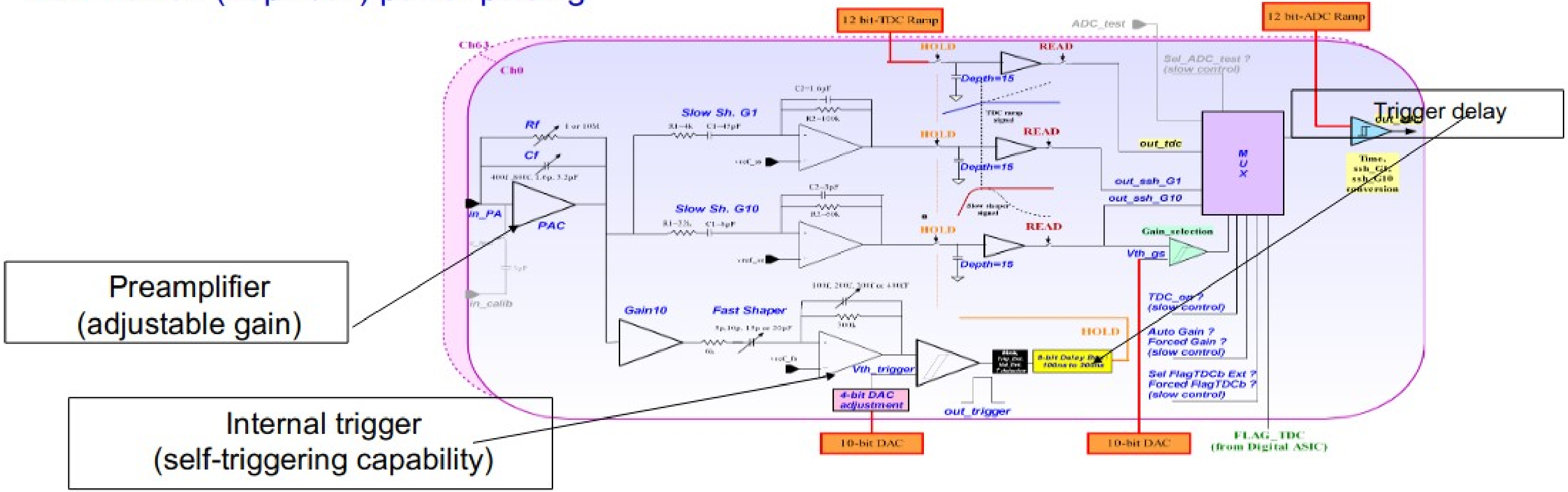
Current prototype (see later) is equipped with all of these PCBs

Very Front End ASICs(see R. Poeschl's talk)

SKIROC (Silicon Kalorimeter Integrated Read Out Chip)

- SiGe 0.35µm AMS, Size 7.5 mm x 8.7 mm, 64 channels
- High integration level (variable gain charge amp, 12-bit Wilkinson ADC, digital logic)
- Large dynamic range (~2500 MIPS), low noise (~1/10 of a MIP)
- Auto-trigger at ½ MIP, on chip zero suppression
- Low Power: (25µW/ch) power pulsing

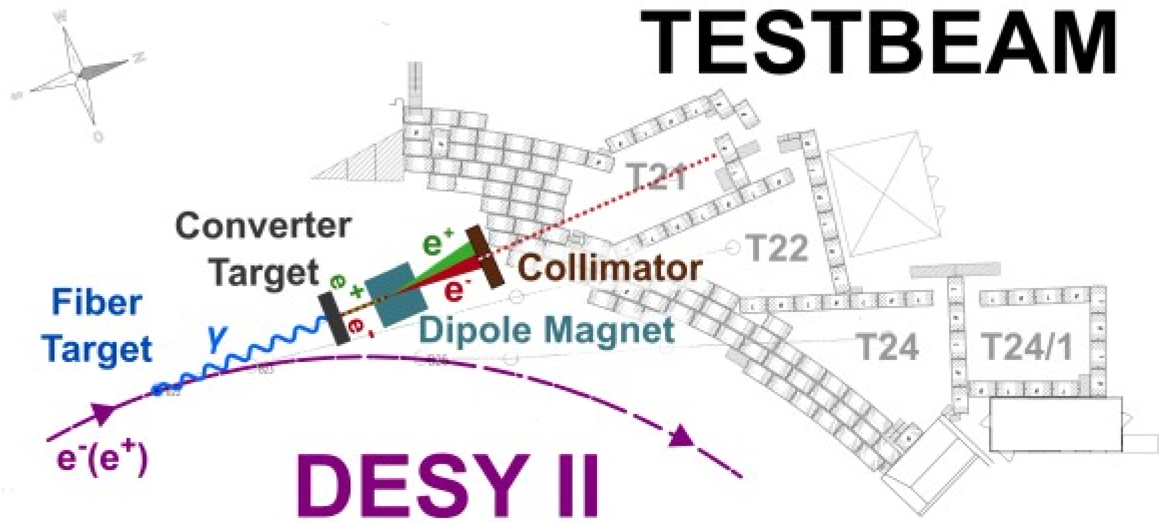




(see R. Poeschl's talk)

- Sensors
- DAQ
- Mechanics
- … all in R. Poeschl talk this morning

Testbeams DESY 2021-2022

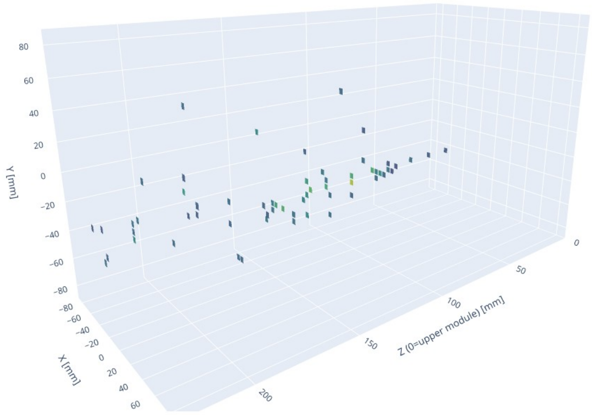


The measurements leading to these results have been performed at the Test Beam Facility at DESY Hamburg (Germany), a member of the Helmholtz Association (HGF)

Test Beams DESY 2021-2022

- **DESY offers low-energetic beams of 1-6GeV (e-, e+)**
- **15 layers with 1024 readout cells each**
  - **5.5mm si pads**
  - LHC calorimeter scale
  - But it fits in a suitcase
- **4 weeks in total**
- ~3 weeks of commissioning and “training”
  - Mechanical structure (adding or removing the tungsten plates)
  - New and continuously improving DAQ and online monitoring tools
  - New semi-online monitoring tools
  - Hold values, gain optimization, Threshold optimization, single cell calibration, etc

Flexible stack:
absorber is optional



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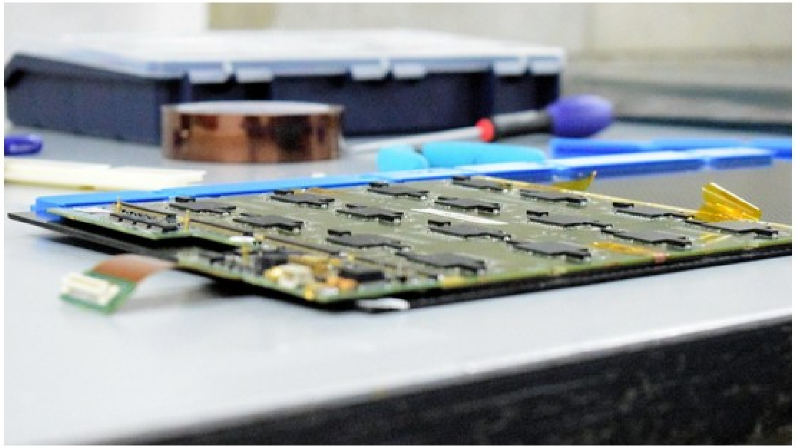
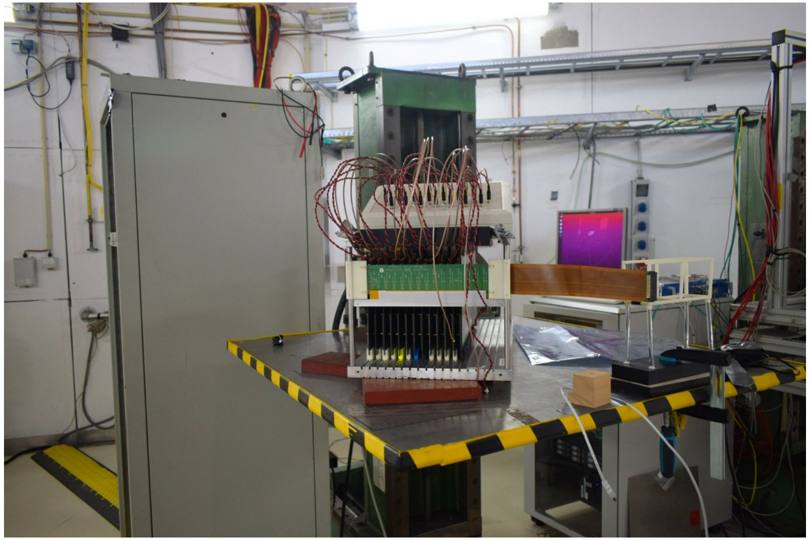
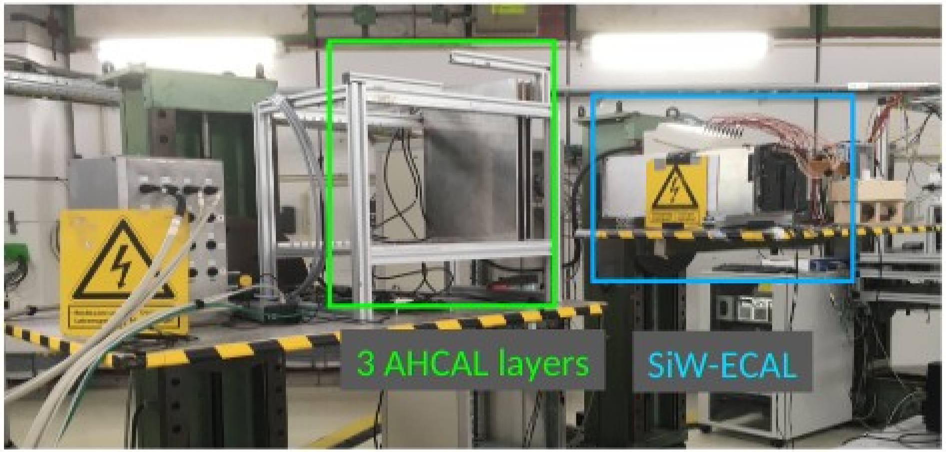
Test Beams DESY 2021-2022



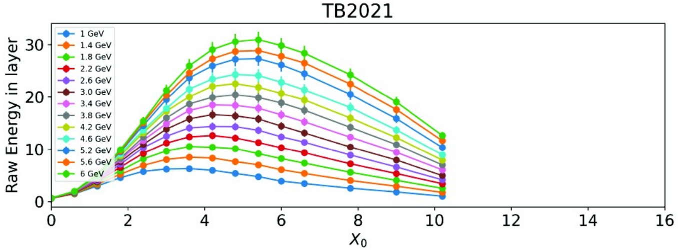
CALICE IFIC INSTITUT DE FÍSICA CORPUSCULAR

Test Beams DESY 2021-2022

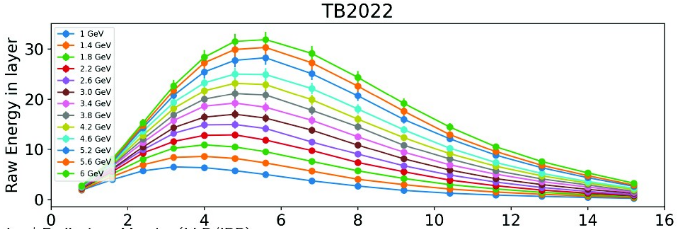




SiW-ECAL + AHCAL DAQ test @ DESY in March 2022



Preliminary simulation



Preliminary simulation

Detector commissioning: pedestal and noise

https://arxiv.org/pdf/1401.7095.pdf

Coherent noise source identification in multi channel analysis

T. Frisson*[1] and R. Poeschl[1]

[1]Laboratoire de L'accélerateur Linéaire (LAL), CNRS/IN2P3, Orsay, France

May 4, 2021

- "The goal is to identify and characterize dissociable noise sources in a multi channel systems. This method cannot separated noise sources which affect exactly the same set of channels. In this case, the noises sources are processed as a single source. We consider a system with N channels. "
- "Each channel **k** is affected by an incoherent noise source **I_k** and Nc coherent noise sources (**C1_k, C2_k,... CN_k**). We assume that all noise source distributions are Gaussian and independant."

Detector commissioning: pedestal and noise

channel i is:

$$\sigma_i^2 = \sigma_{I_i}^2 + \sum_{j=1}^{N_c} \sigma_{C_i^j}^2 \qquad (1)$$

The covariance matrix element from the two channels i and k is expressed by:

$$cov(i,k) = \delta_{ik}\sigma_{I_i}\sigma_{I_k} + \sum_{j=1}^{N_c} \sigma_{C_i^j}\sigma_{C_k^j} \qquad (2)$$

where:

$$\delta_{ik} = \begin{cases} 1 & \text{if } i = k \\ 0 & \text{if } i \neq k \end{cases} \qquad (3)$$

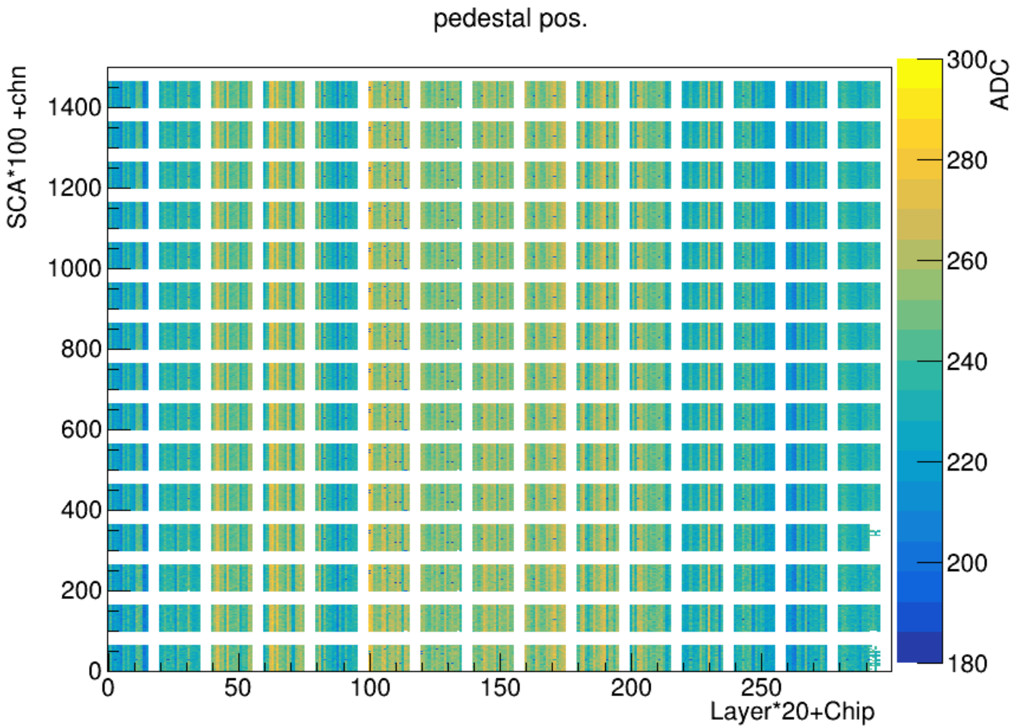
The covariance matrix element can also be determined from the data:

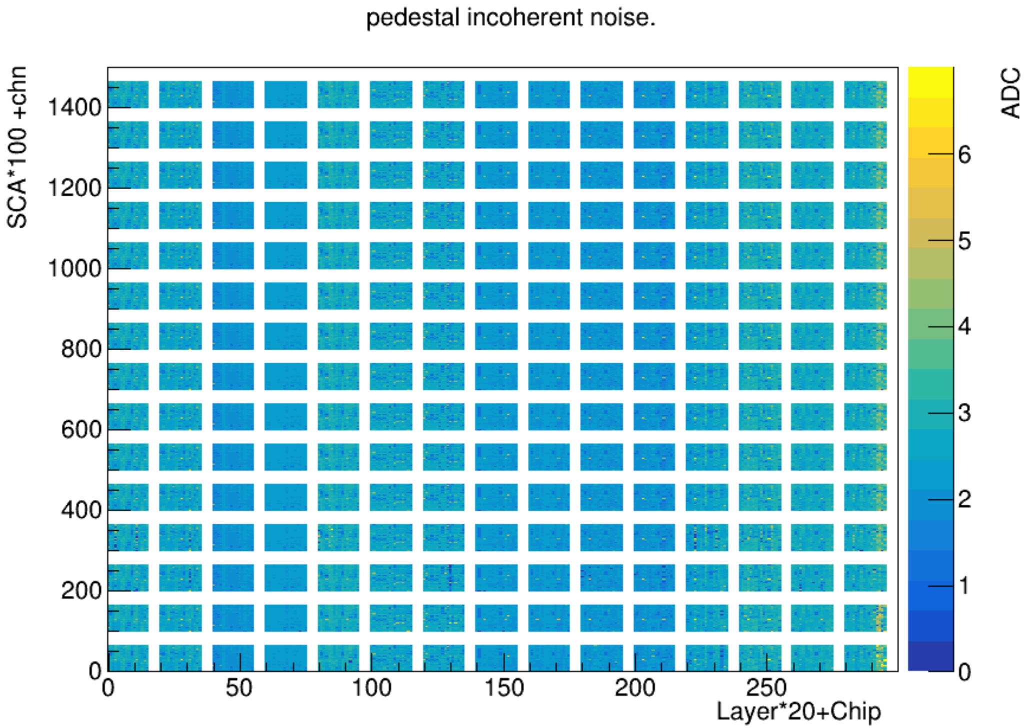
$$cov_{Data}(i,k) = \frac{\sum_{n=1}^{N_{event}} (A_i(n) - \mu_{A_i})(A_k(n) - \mu_{A_k})}{N_{event}} \qquad (4)$$

Measured amplitud if no hit

Pedestal position → calculated as simple histogram Mean

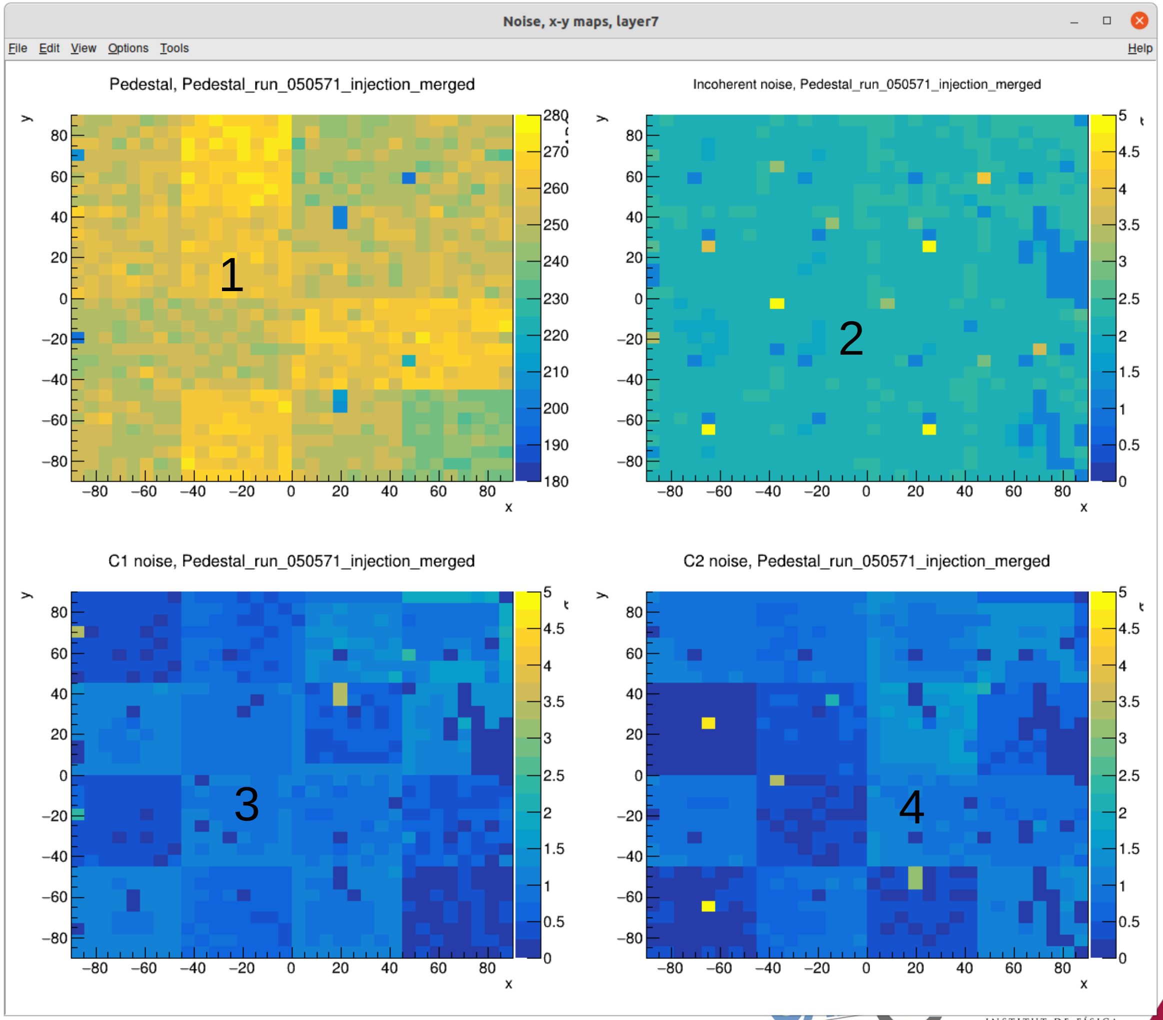
Pedestal position and incoherent noise





Layer 7, slab30 FEV12 sk2a, 500um

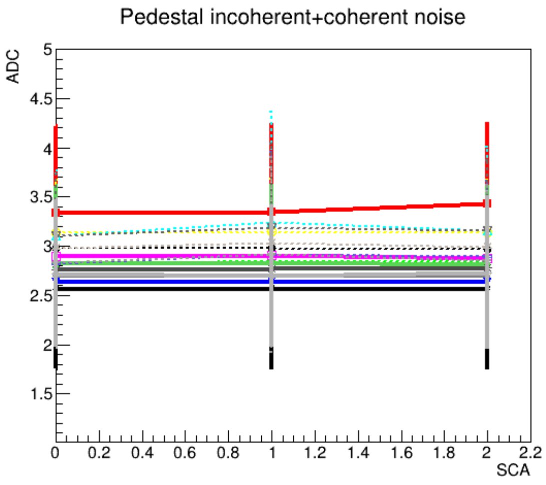
- 1) Pedestal map
- 2) Incoherent noise map
- 3) coherent noise map (c1)
- 4) coherent noise map (c2)



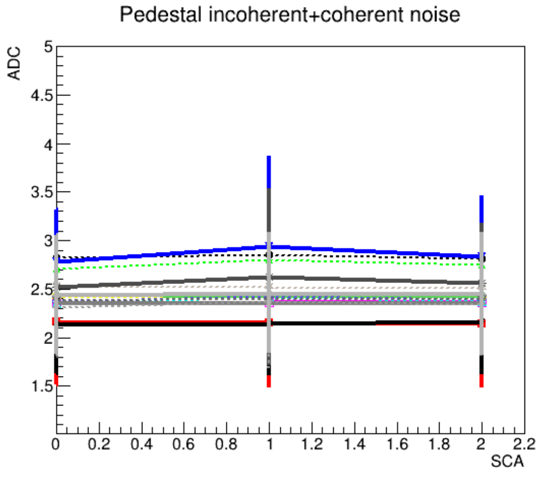
Few channels are off
These are usually seen as noise sources (FEV10/11/22)
Routing issues (addressed in next generation)
Only BGA

Noise: Chip on board vs BGA

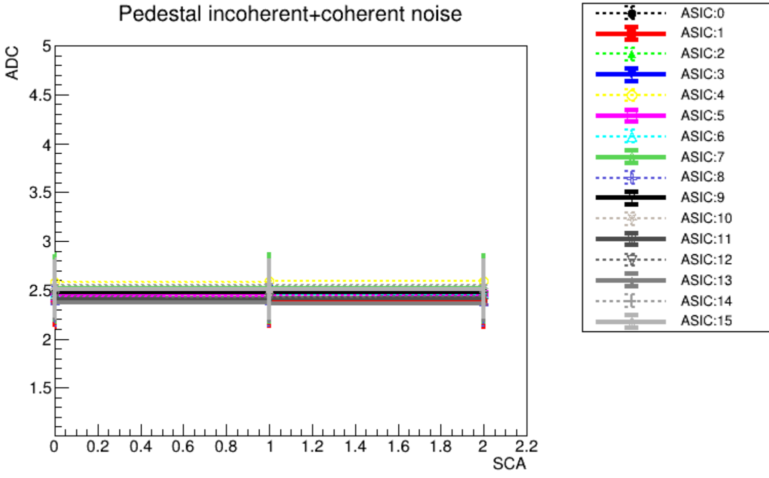
COB



FEV12

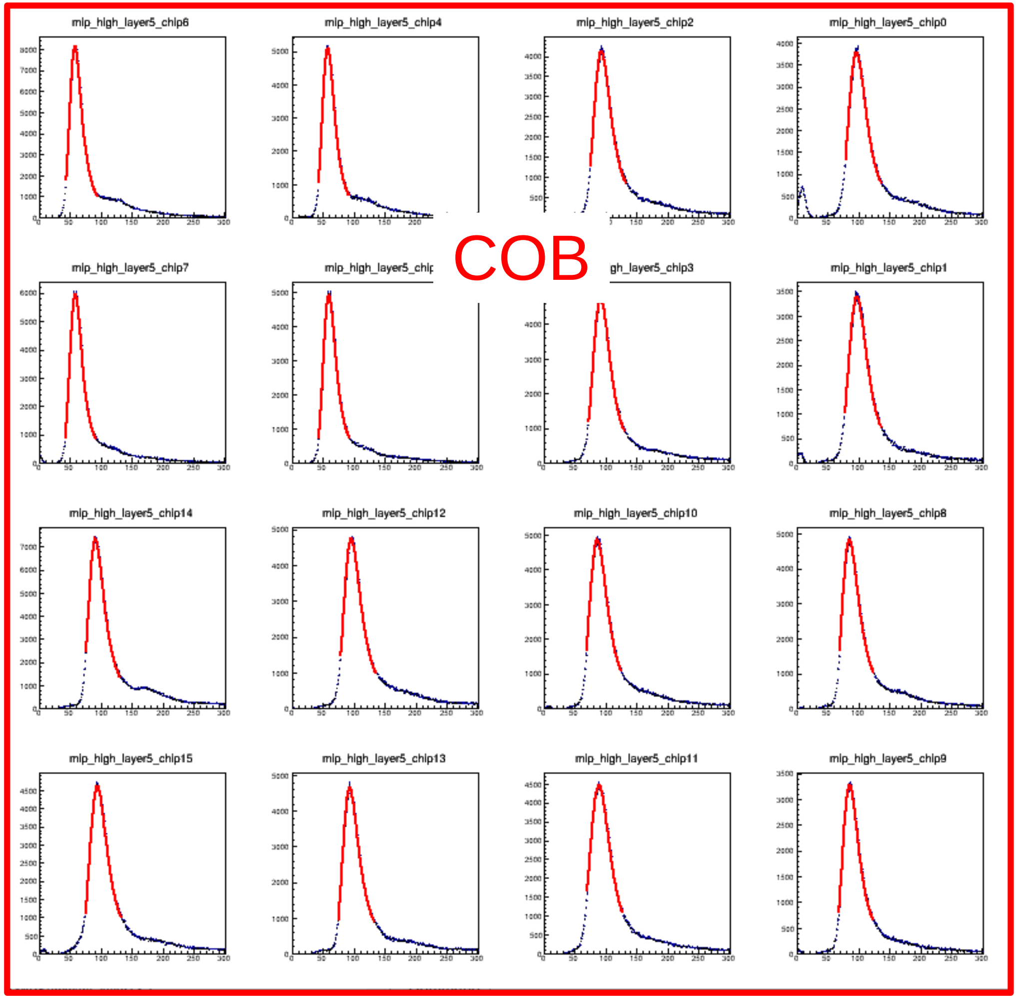


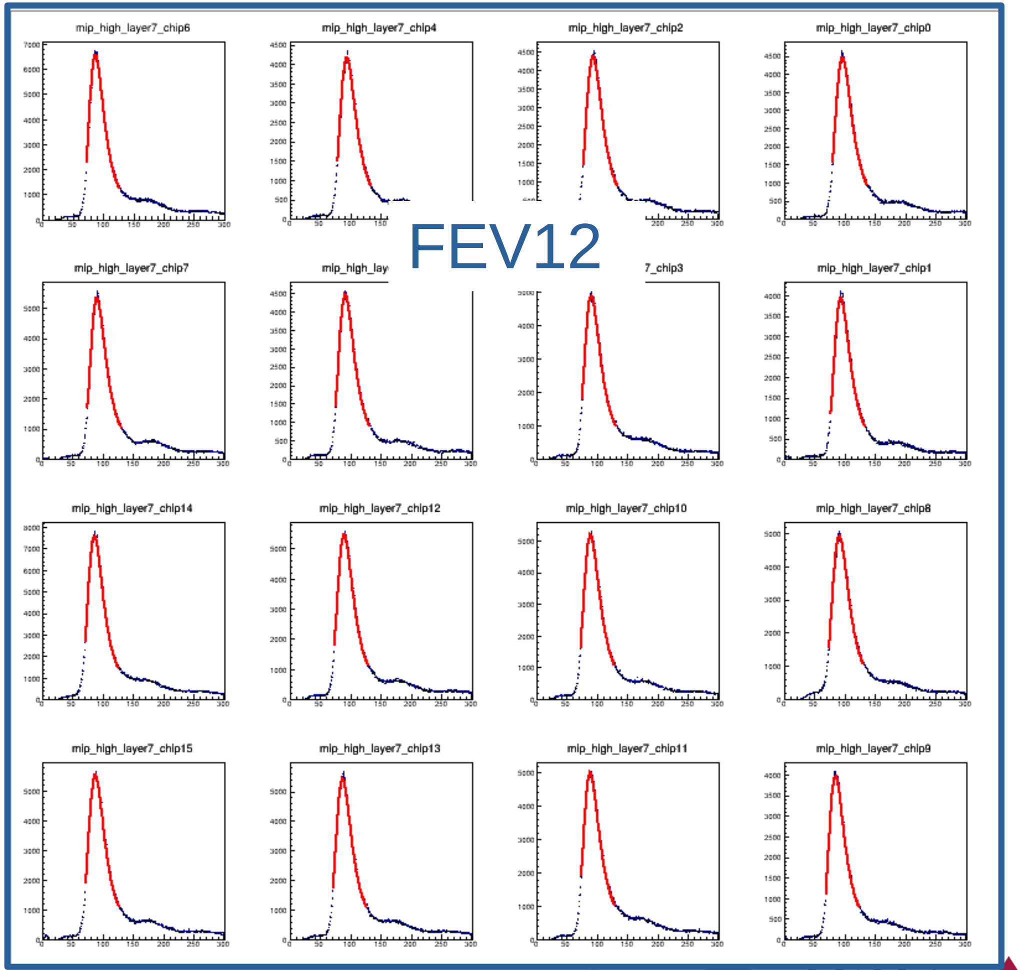
FEV13



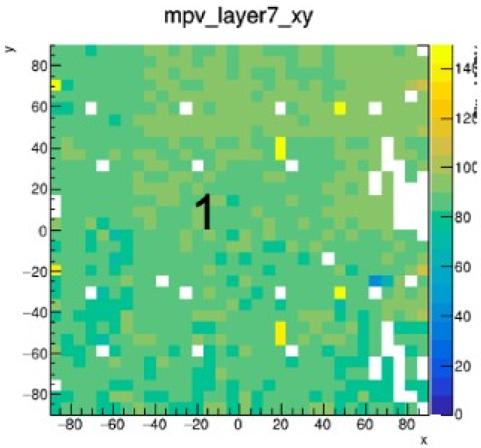
- Average of sigma for all channels in the same chip
  - The error bar is the std of these values
- Newer PCBs, with optimized power distribution shows better behavior
- COB has a competitive performance
  - Despite being almost not equipped with passive components as decoupling capacitors

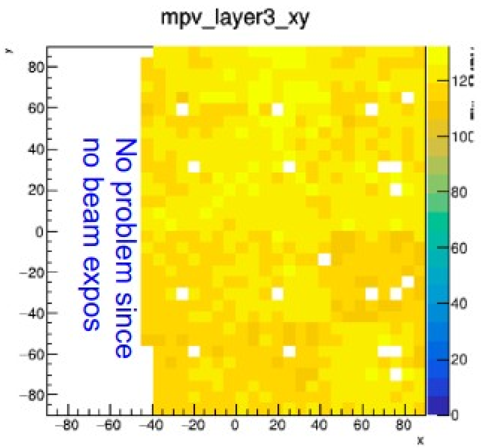
MIP calibration: COB vs BGA



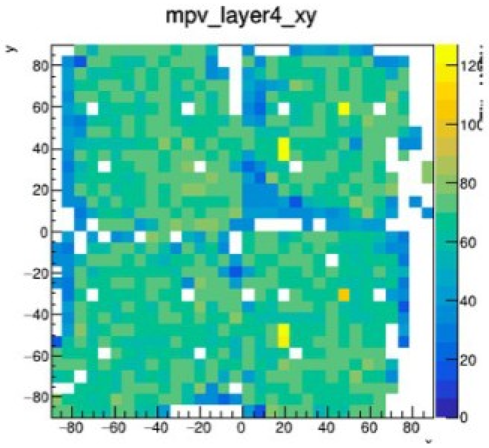


MIP calibration





- We have good layers ...
  - Homogeneous response to MIPs over layer surface
  - Here white cells are masked cells due to PCB routing
    - Understood and will be corrected

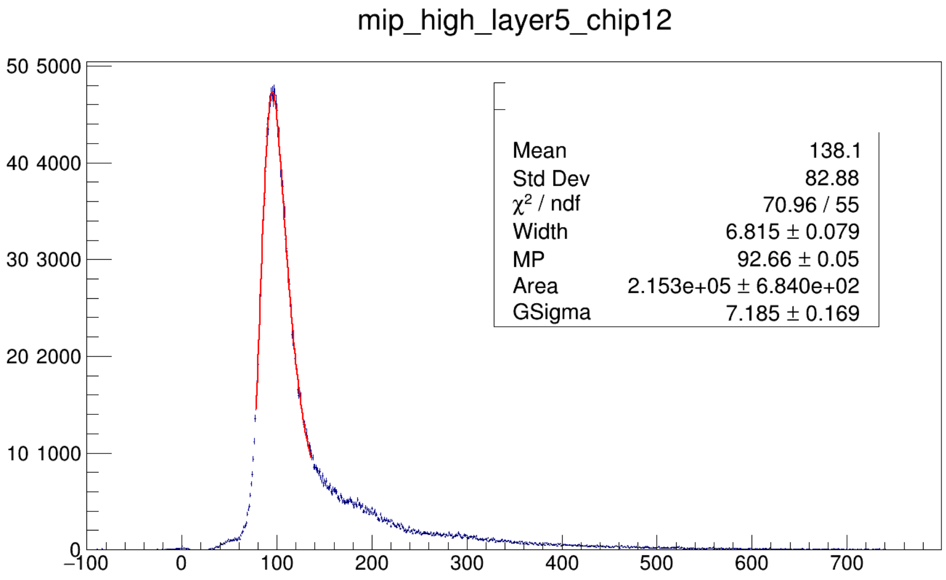


... and not so good layers

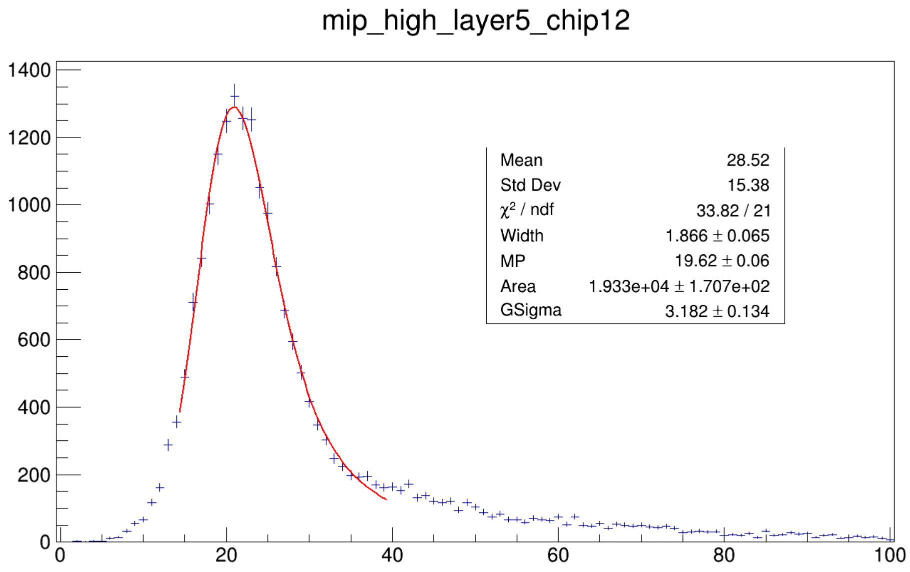
- Inhomogeneous response to MIPs
  - Partially even no response at all, in particular at the wafer boundaries
  - To be understood, may require dedicated aging studies
- Have since last week access to the different stages of the ASICs
  - => major debugging tool
- In any case less good layers will be replaced in coming months

DESY (16GeV) vs ILC (1-100GeV) gains

DESY gain

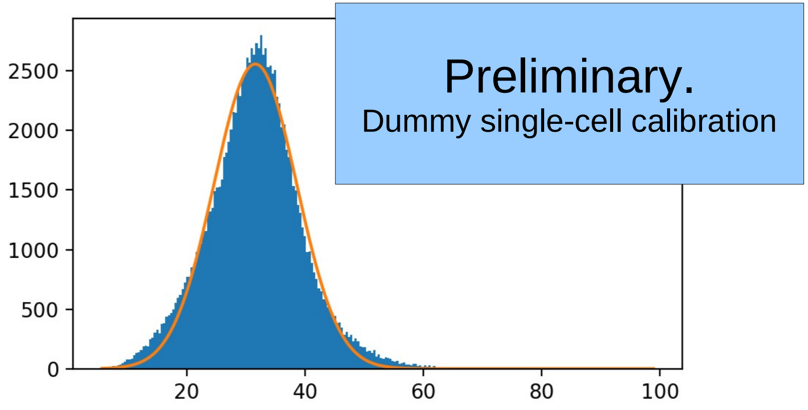


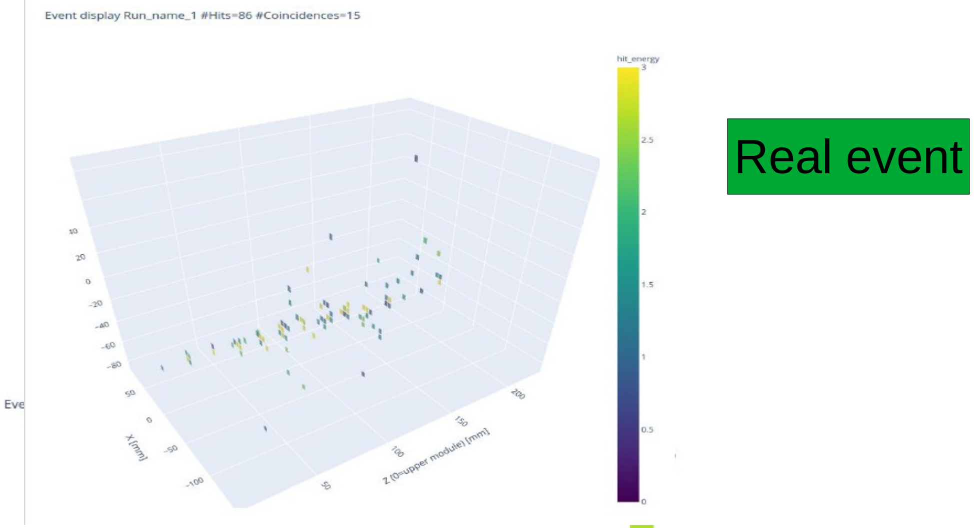
ILC gain

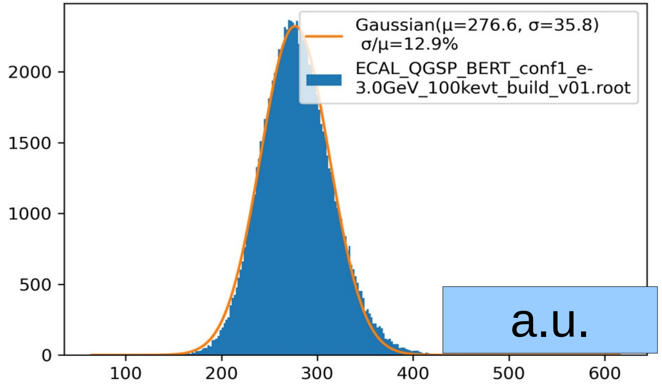


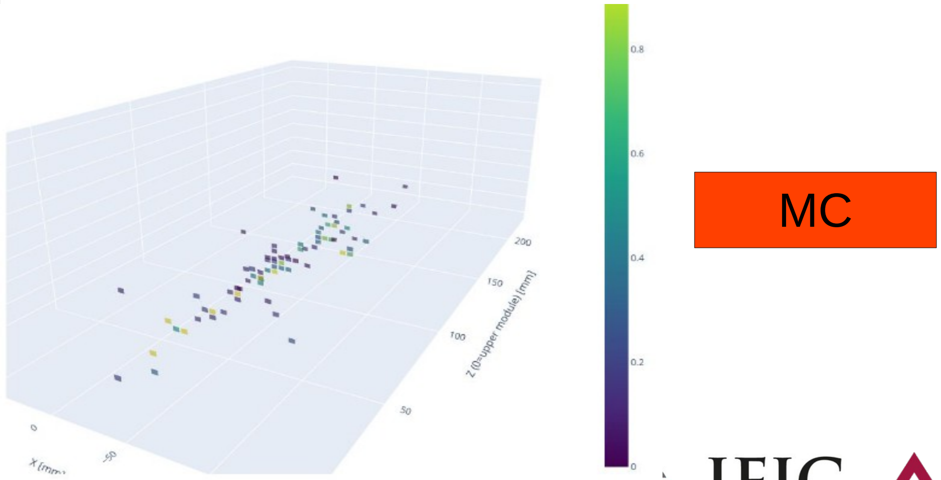
Preamplifier 1.2pF vs 6pF ~ x4.73

Low energetic electromagnetic showers

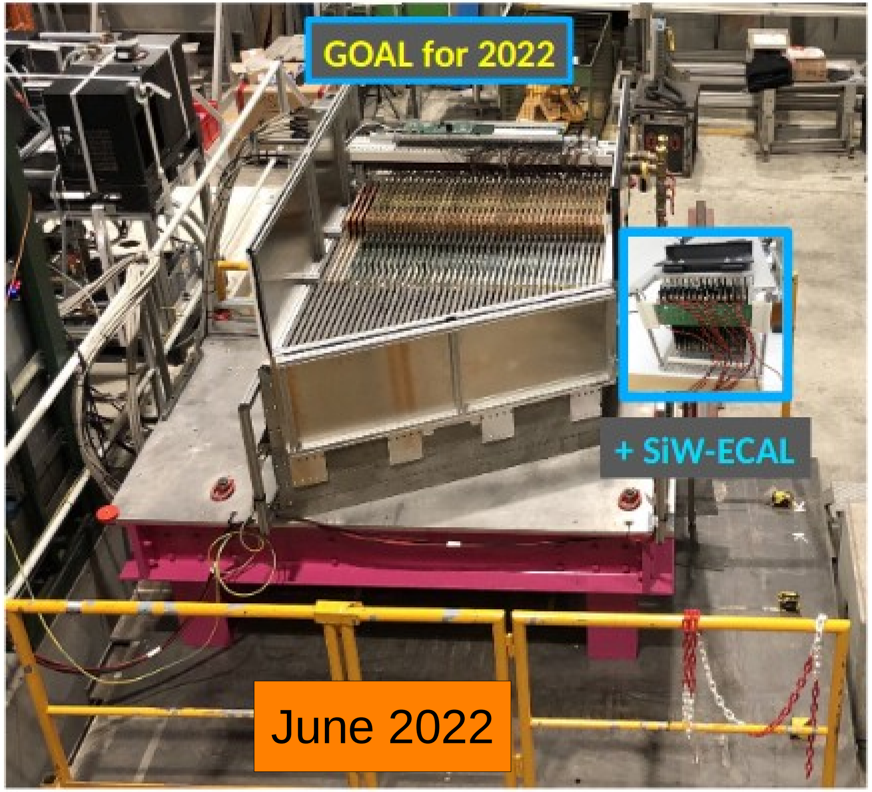


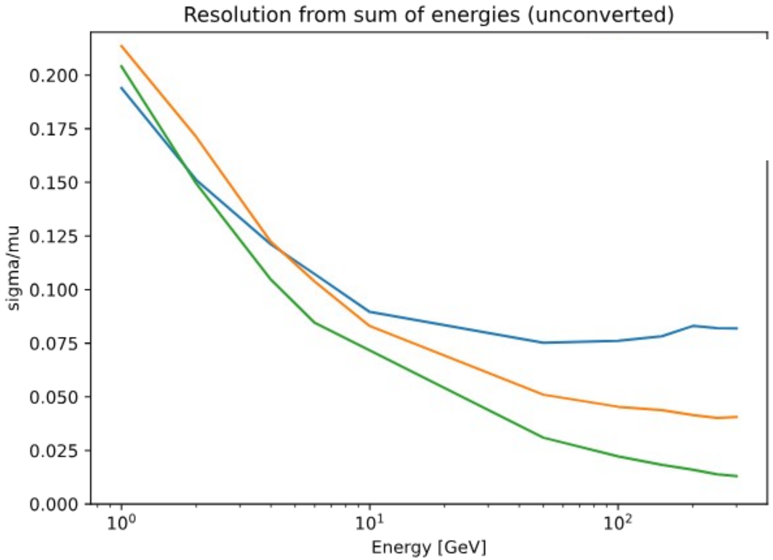






Next stop: CERN (together with AHCAL)





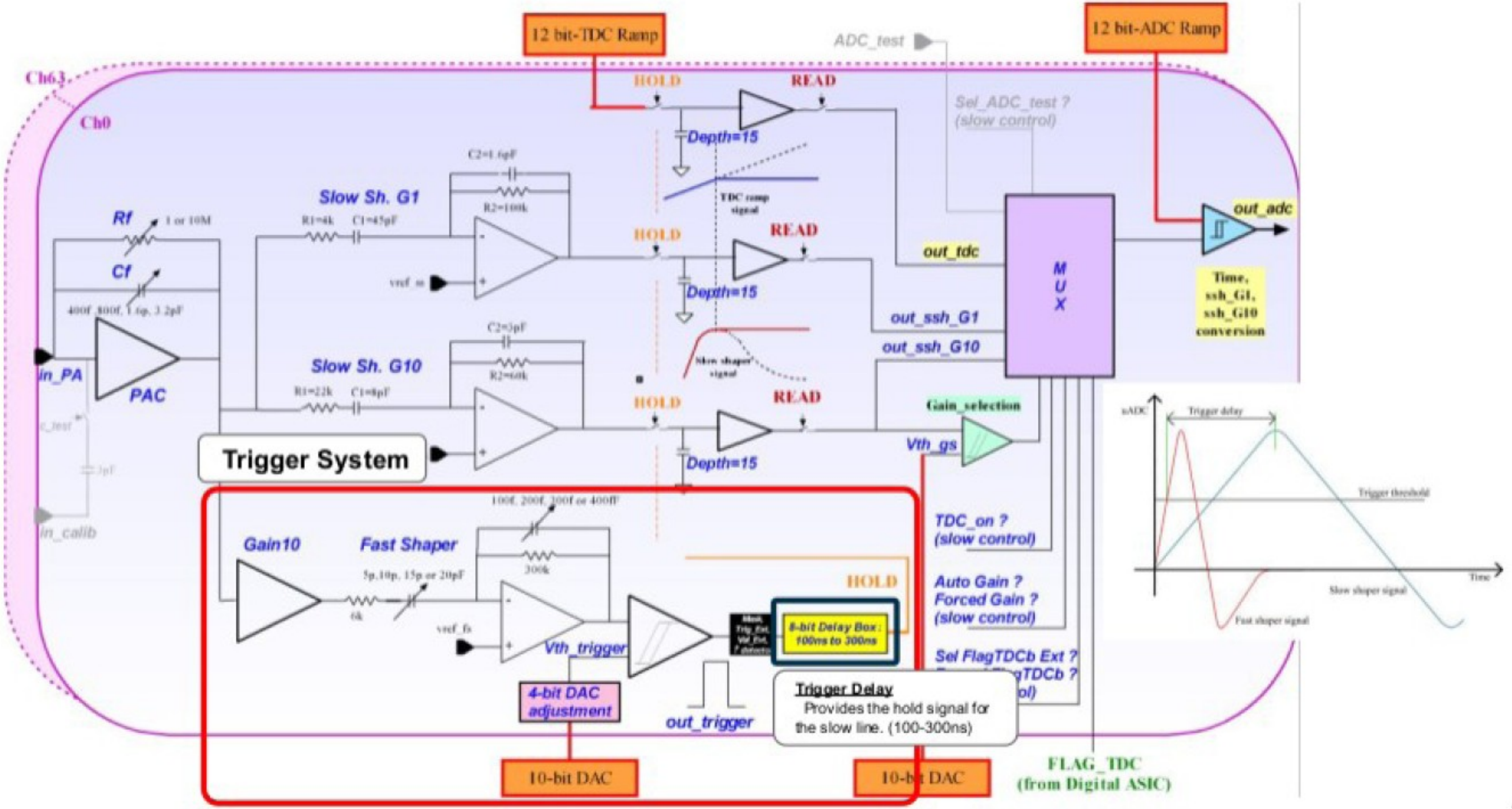
Simulation (only SiW-ECAL)
15 layers:
– 14.7 X0
– 21.2 X0
– 28.9 X0 (and 24 layers)

Summary

- The SiW-ECAL prototype
  - 15 layers of 180x180mm^2 with 1024 5.5x5.5mm^2
  - Modular stack: accepts different tungsten distributions and different options for PCBs
- Intense campaign of BT 2021-2022
  - After a long hibernation due to COVID
  - Detailed commissioning at DESY (low energy electrons)
  - Detailed input obtained for the ongoing new optimized PCBs design and production
- Next stop at CERN
  - common running with Analogue Hadronic Calorimeter of CALICE
  - High energy leptons and hadrons

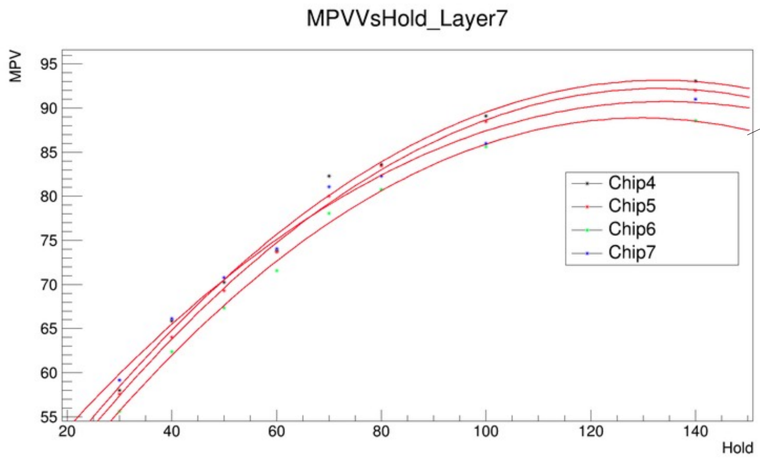
back-up

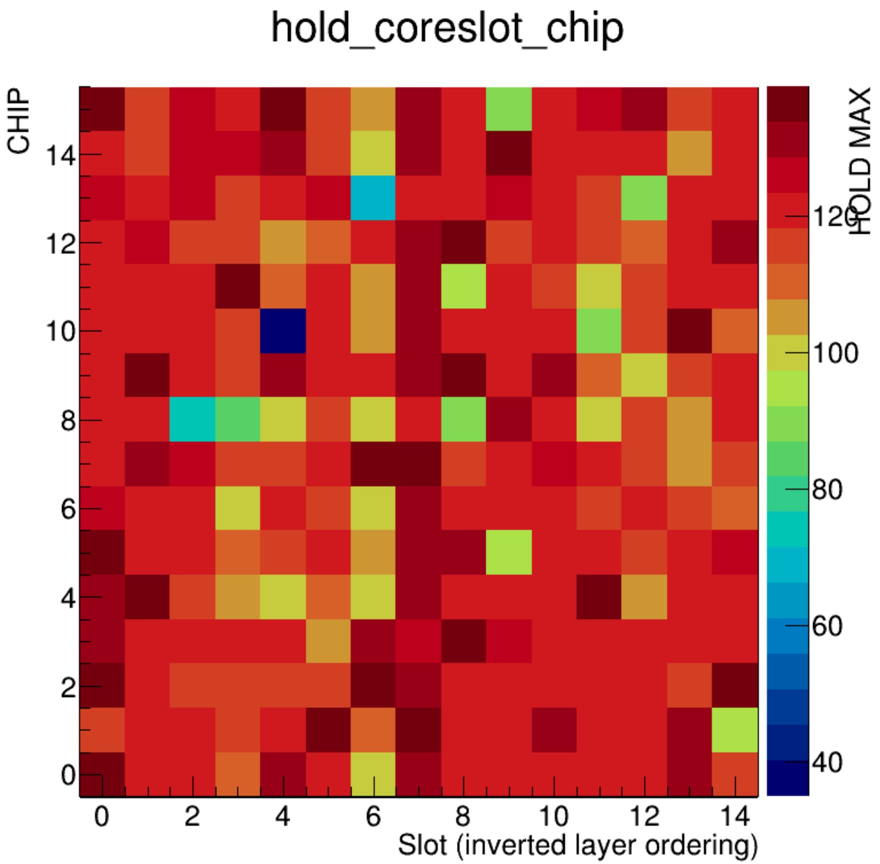
Detector commissioning: hold-value



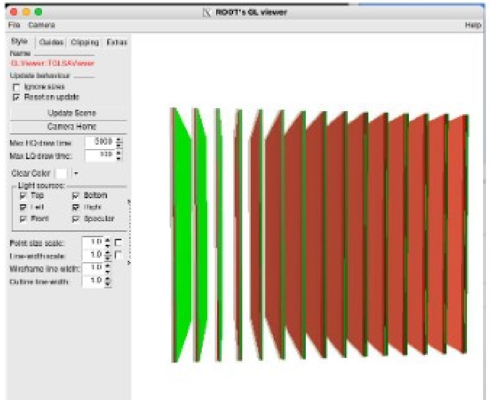
Detector commissioning: hold-value

- Done at DESY with beam



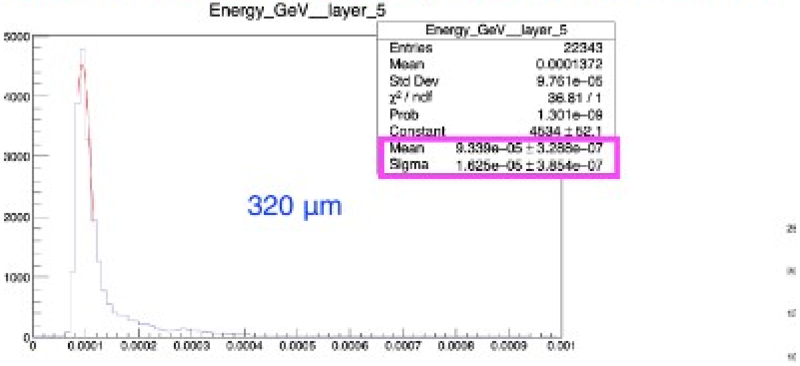


Simulation

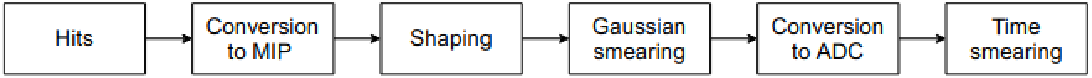


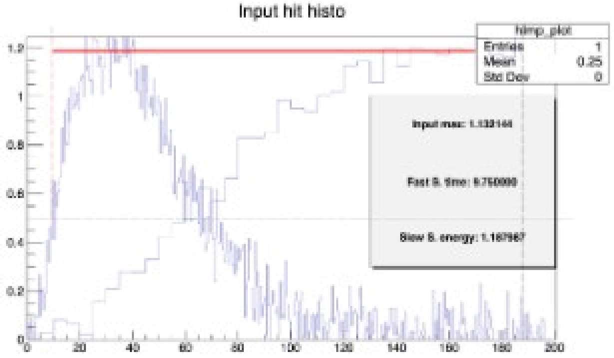
Digitization

Conversion to MIP scale (electrons @ 3 GeV



Raw simulation ⇒ info. resembling detector output, including readout effects





- Hits: starting point from raw simulation.
- Map energy deposited to MIP scale.
- Simulate pulse shaping in the readout electronics + saturation effects.
- Add smearing: noise term in detector cells/readout.
- Conversion to ADC, time smearing